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SOME HABITAT RESPONSES OF THE LARGE WATER-STRIDER, GERRIS REMIGIS SAY

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I. Introduction

The large water-strider, *Gerris remigis* Say (Fig. 1), is one of our most interesting and familiar aquatic bugs. During the years 1911–1913 inclusive, I made a somewhat intensive study of the responses of this species to the physical conditions of its environment, in the vicinity of Urbana, Illinois. This study has been continued, intermittently, up to the present time. The present publication forms only a part of the entire investigations. Part of this paper treats of observations made near Urbana, Illinois, and part treats of observations made near Syracuse, New York.

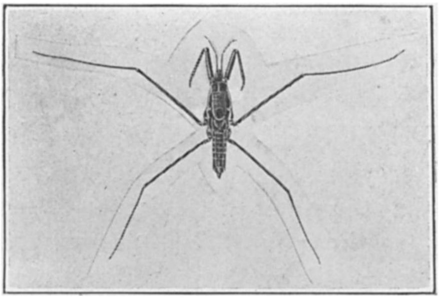

Fig. 1. The large water-strider, *Gerris remigis* Say, natural size. (Folsom.)

In the summer of 1911, a severe drought occurred in the vicinity of Urbana. In fact so extended was the period of dry weather, that many streams in the region, that usually were to be classed as permanent, became absolutely dry, and others were reduced to a few isolated pools. Water-striders, *Gerris remigis,* were trapped in many of these pools. As the gerrids belonging to this species are *mainly* apterous insects, they were unable to migrate by flight to some other body of water. Because of this, serious results might accrue to those individuals that were isolated in such situations when the pools became dry. It was a matter of interest to know what would become of these hemipterons when the water entirely disappeared. Therefore, a number of observations were recorded in connection with this subject.

II. PHYSICAL CONDITIONS OF AND BEHAVIOR IN BROOK HABITAT DURING SEVERE DROUGHT AT WHITE HEATH

1. Description of Physical Conditions.—Frequently certain physical conditions were found to exist in brook habitats in the early stages of droughts that had a direct bearing upon the very existence of the water-striders, *Gerris remigis*, but which will be mentioned here only very briefly. I wish to refer particularly to a brook, flowing partly through a forested region, near White Heath. This brook is situated about eighteen miles southwest of Urbana, and the physical conditions to be considered are such as existed during a drought, in the summer of 1911. During the earlier periods of this drought, I often found, in the drying brook bed, small pools of water not entirely isolated from each other. (In Figs. 2 and 3 are shown drought stages in the bed of the brook near White Heath that are very similar to those under consideration. The only difference here, of importance, is that the pools are in somewhat earlier drought stages than are those to which I have referred.) Such pools were connected by means of riffles not more than 6–12 inches wide (Figs. 2, 3). When food became scarce in pools of this character, or when a scum, often due to bacterial growth (Fig. 3), formed on their surfaces, I have observed that the water-striders made their way from one pool to another, by means of these small riffles of water, until such connecting links disappeared and the majority of the pools became dry. Eventually the gerrids were concentrated on the surfaces of the few isolated pools that remained. Sometimes, the bacterial growth, which was of a gray color, caused the death of hundreds of water-striders.

Such pools as have been mentioned persisted longer in that part of the brook's course that extended through the wooded region. In such a region the pools were larger, with a greater volume of water, than frequently was the case in more exposed situations. These conditions were due primarily to the protection afforded to the

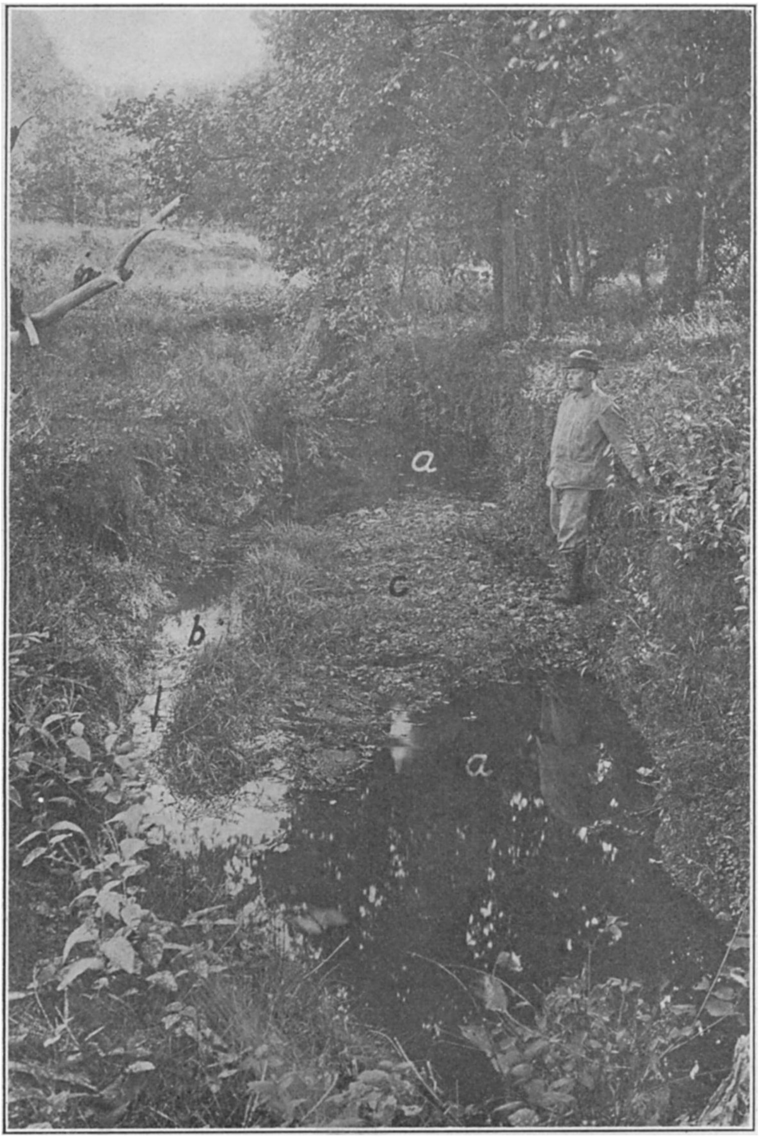

FIG. 2. Detail of brook near White Heath, along margin of forested region, showing conditions during early stage of drought (July). Arrow indicates direction of current. *a,* pools on surface of which water-striders, *Gerris remigis,* live; *b,* small riffle connecting two pools; water-striders pass from one pool to another by means of such riffles. *c,* dry bed of brook exposed during early and late stages of drought. (Original.)

water by the surrounding trees. There, undoubtedly, is less evaporation in a region of this character than is true in those parts of the brook which are situated in regions lacking both trees and shade and are thus exposed to a high temperature and to the full effects of the summer sun. Very similar facts were observed near Charleston, Illinois, by Adams (1915, pp. 65, 66) in connection with a small stream in a forested area. He makes the following statement:

> This small temporary stream in a ravine formed the southern boundary of the area examined. . . . At the season of our examination it was a series of small disconnected pools. . . . On the surface of the pools were numerous specimens of a water-strider, *Gerris remigis*. The forest cover is undoubtedly an important factor in the preservation of such pools, as it controls the evaporating power of the air.

In this connection I wish to state that the water-striders were found in far greater numbers, in the late spring, summer, and early fall, on those portions of the stream that flowed through the forested area. After several years of observation, I have come to the conclusion that the shade and lower temperature are the important factors in influencing the gerrids to remain in such situations. De la Torre Bueno (1911, p. 246) has observed somewhat similar facts, as is indicated in the quotation:

> It [*Gerris remigis*] is to be found most frequently on running waters, although it also frequents still, but to a less extent. . . . They congregate in groups in shady, slow-moving parts of streams, at the tree roots projecting from banks into the water, in the shadow of bridges, and in general in almost any place where they have some shelter from the burning rays of the summer sun.

This observer (1917, p. 201), again writing of *Gerris remigis,* states that:

> These beasties are common and familiar sights to the lover of the quiet flowing waters running to the distant seas. In these haunts, in some still little bay or moveless backwater, under a bridge, or in the shadow of a tree, or in the cool recesses of an overhanging bank, you may see *remigis* gathered in numbers, rowing silently about. . . . Here they rear large families and spend at ease the sultry dog-days.

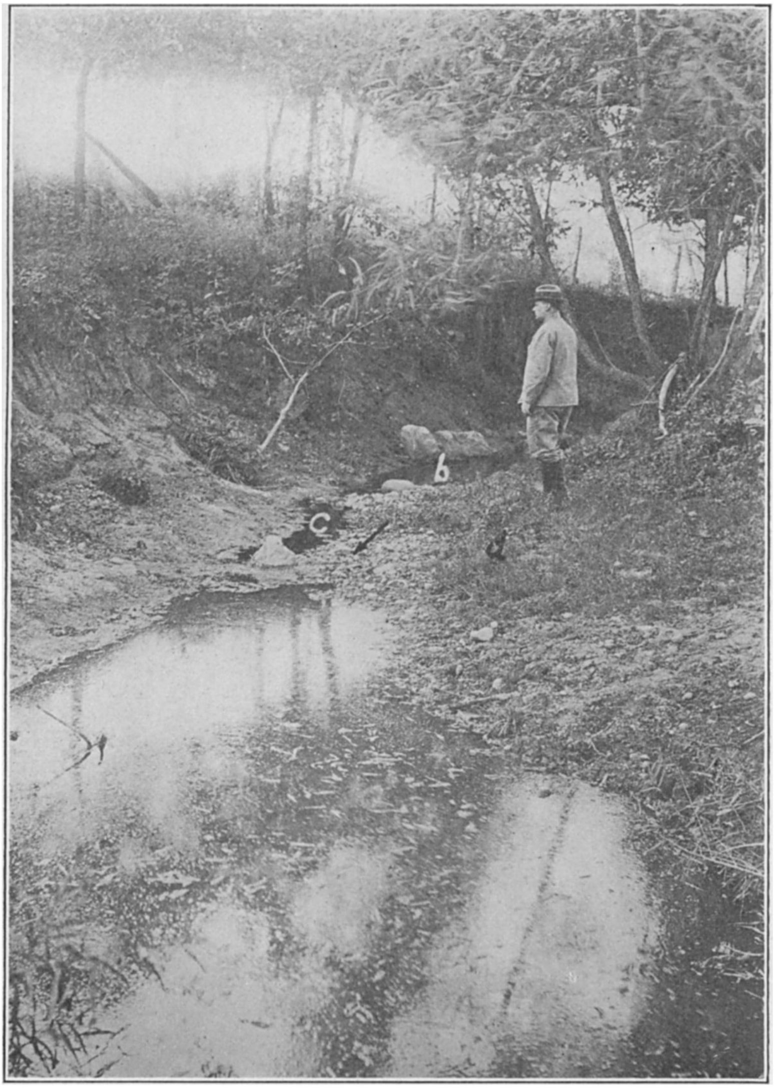

FIG. 3. Detail of brook near White Heath, along margin of forested region, showing conditions during a later stage of drought than indicated in Fig. 2 (August). Arrow indicates direction of current. *a,* pool showing scum on surface, formed by bacterial growth, which frequently kills water-striders in large numbers; *b,* pool on surface of which water-striders, *Gerris remigis,* live, surface being free from scum; *c,* small riffle connecting two pools; water-striders pass from one pool to another by means of such riffles. *d,* dry bed of brook exposed during early and late stages of drought. (Original.)

Attention has been directed to some of the physical conditions that existed in a brook water-strider habitat in the early stages of a drought. Certain features of such a habitat in the later drought stages, will now be considered. So far as I am aware, there are no records in the literature on aquatic Hemiptera, that describe the responses of these gerrids, *Gerris remigis,* after the water in their habitat actually disappears. The statements given here are very condensed records taken, chiefly, from my extensive field notes of the summer of 1911.

Late in the summer a trip was made to White Heath for the purpose of examining a number of isolated pools, on the surface of which water-striders were trapped, in the bed of the brook near that place. Particular attention was directed to one pool in which the water had evaporated rapidly during the previous week. It was examined about 8:00 A.M. and at that time the dimensions of the pool were approximately $12 \times 5 \times \frac{1}{2}$ inches. It was evident that the pool would be completely dry before night. Evaporation was taking place rapidly, as the atmosphere had been very dry for several days. The heat had been intense for a number of weeks, a temperature of 90°–100° F. not being uncommon.

2. *Behavior in a Drying Pool.*—There were twenty gerrids trapped on the surface of the pool, already mentioned. The insects did not move about very much on the water-film. They were very quiet, frequently remaining, practically, motionless for several consecutive minutes. There was no behavior on the part of the hemipterons that indicated any attempt to escape from the unfavorable surroundings. The members of this species being *largely* apterous forms and their optimum habitat being permanent brooks and streams of moderate size, with a current of medium velocity, it was, perhaps, not strange that they evinced no responses that showed definitely adapted behavior of a character suitable to cope with such abnormal conditions and unusual habitat changes. At 2:00 P.M. the pool was almost dry, and by 3:30 P.M.

there was little to indicate its location except a small area of rapidly drying mud.

3. *Hibernation and Æstivation.*—A number of writers —among others Uhler (1888, pp. 268, 275), McCook (1907, p. 265), and Kellogg (1908, p. 198)—on water-striders have stated that during hibernation these gerrids burrowed into the mud, under the banks of streams, at the bottom of water under stones and roots of trees, and at the bottom of the pool under roots or stones; and as some investigators, Tower (1906, p. 245), for example, consider hibernation and æstivation to be "fundamentally one and the same process," I was interested to observe whether the gerrids would burrow into the mud, or into some moist, sheltered spot under the banks of the brook, and remain there in a quiescent condition, a state of æstivation, until the rains came. However, there were no definite responses of such a character. I doubt whether water-striders do æstivate in the true sense of that term during periods of drought, although more evidence is necessary before a definite statement can be made.

As will be noticed later, the gerrids do respond to contact stimuli. Generally such a stimulus resulted in inhibiting locomotor activity and the insects remained motionless with their bodies closely applied to some solid object in the bed of the brook. This might prove to be a piece of dry mud, a stick of driftwool, a stone, or a clump of dead leaves. As a result of contact stimuli, sometimes they would crawl under such objects as have been enumerated and remain there for a considerable length of time. I have recorded observations which prove that they stayed in such situations from a few seconds to thirty minutes. The gerrids might remain in places of this character for even a longer time, as I have noticed, on a few occasions, that they were still there when I discontinued my observations for the day. However, I was not able to find them in the same situation the next day, even after most carefully marking the place. On several other occasions, I have made similar observations, but never was I able to discover the water-striders the following day.

It is possible that there was a trifle of moisture in such situations, and that it was this, acting as a stimulus, which kept the gerrids there. But during these periods of drought—accompanied, as they are, in the prairie regions of Illinois with excessive temperature and glaring sunlight—I have failed, positively, to find moisture in such places, except under large objects, which were not present in the bed of the brook. Frequently, however, I have noticed that under these objects, in the brook bed, the temperature was slightly lower and of course there also was the shade. It is probable, also, that evaporation is reduced in such protected places. That certain arthropods are sensitive to the evaporating power of air is known from the work of Shelford (1913, pp. 85–102), who has demonstrated that the yellow-margined millipede, *Fontaria corrugate* Wood, and the ground beetles, *Pterostichus adoxus* and *Pterostichus pennsylvanicus,* respond negatively to the increased evaporating power of air. Therefore, lower temperature, shaded surroundings and reduced evaporation may be the three factors that accounted for the water-striders remaining in situations of the character that have been mentioned. Of course if it was proved that they stayed there day after day, this would indicate the possibility of their tiding over a short drought in such protected places. I have noticed on a few occasions, at least, that the gerrids have died, if away from water, when exposed to glaring sunshine and high temperature, during a drought. I also have observed, when the water in my laboratory aquaria was allowed to evaporate gradually, until it entirely disappeared, that, sometimes in a few hours and at other times in a few days, the gerrids died. This occurred, not infrequently, when the temperature was only 85° F.

During hibernation, there is no question about water-striders remaining quietly in one place for a long period of time. But it must be recalled that the temperature is low at such times, and that they frequently seek dry situations. The subject of hibernation will be discussed at greater length in another paper. I may say, however, that these water-striders do not hibernate in any of the situations mentioned by the writers quoted, except under the banks of streams, and then away from the water. The positive thigmotactic responses of these gerrids have been observed frequently during periods of hibernation. At such times they formed tangled masses, which were due to the water-striders crowding closely together. These facts were recorded in my field notes as early as the winter of 1912–1913. It is interesting to recall that Essenberg (1915, pp. 397, 400) has observed similar responses in the case of *Gerris orba* Stål.

4. Initial Responses in Dry Bed of Brook.—With reference to the water-striders in the dry bed of the brook at White Heath, it appeared as if the gerrids might die right where they were, for no movements occurred for approximately ten minutes after the water had disappeared. Soon they began to move away. I can not state absolutely what was the stimulus that caused the initial locomotor responses, although it probably was the total disappearance of all moisture, as this was the only evident change in the external conditions. Singly and in small groups they jumped and walked in an ungainly fashion from the site of the former pool. While it was evident that the water-striders were less accustomed to locomotion on the land than they were to locomotion on the water, yet they made fairly good progress along the bed of the stream.

The evidence that the initial locomotor responses of the gerrids, away from the pool in which they had been living, were due to the drying up of the water is further supported by the following facts: Very frequently, I have observed that when water-striders were removed from the surface of a pool in a stream, or from an aquarium, where they had been kept in captivity, and placed on the ground or on some other solid surface that they at once became active. This was true even if the gerrids previously had been inactive. They would start to jump and walk in a very agile, if ungainly, fashion, and made rapid progress, especially if they were on a smooth and level surface. It seemed that the transference from the water-film to a solid surface—for all other conditions were as before—was a sufficient stimulus to cause internal changes in the insects, that set free energy in the form of locomotor activity. To induce this result there was but one change in the conditions. In this connection I wish to direct attention to a statement by Jennings (1906, p. 285):

> Often, of course, stimulation does rouse an organism to increased activity. But even in this case the activity is due to the release of internal energy. It may, therefore, continue long after the stimulation which inaugurated the release has ceased to act. Such continuance thus does not necessarily imply continued action of the stimulus. In many cases the specific stimulus to action is only the *change* of conditions.

At this point, it may not be out of place to refer to certain observations which, possibly, may have a bearing on the locomotor responses of the gerrids, after the drying up of the pool of water. Abbott (1918, p. 234), in connection with some responses of land isopods, *Oniscus asellus* Linn., *Porcellio rathkei* Brandt, and *Porcellio scaber* Latreille, to humidity and evaporation makes the following statement:

> So far as observation shows, the effect on land isopods of exposure to a dry atmosphere, including the first effect in desiccation experiments, is an increase of activity. This is a useful adaptation, provided the activity carries them to other regions where moisture conditions approach more nearly the optimum.

5. *Behavior in Dry Bed of Brook.*—About ten yards farther downstream there was another much larger pool. Its dimensions were approximately 3 yds. × 2 yds. × 5 in. I was interested to observe how many, indeed if any, of the gerrids would reach it, and thus tide over the period of drought. Of the twenty water-striders present, eight of them went in the direction of the large pool, and wandered in an aimless, awkward manner down the dry

channel of the brook. They first tried one path and then another. These trials resulted in bringing some of the gerrids to the pool, but with reference to other water-striders the trials were not so successful. I found that it was a rather strenuous task to watch all the gerrids, although some of them frequently would come to rest. Without giving too many details, it may be stated that all of the eight individuals, already mentioned, made their way in a blundering fashion to the large pool of water. The first one reached the pool in 5 minutes and 30 seconds, and at once moved on to the surface-film. The time required by the others to reach the water varied to a considerable extent, the average being 14 minutes and 30 seconds. The last individual, of the group of eight, to reach the pool was fifteen minutes in making the journey. Three gerrids out of the eight traversed the distance to the pool with only a limited number of stops and deviations from the straight path. However, this is not to say that the journey was free from erratic movements, on the part of these insects, for such was not the case. The stops usually occurred when the gerrids came in contact with some obstacle in their path. It was not at all uncommon, when the insects moved away from their stopping place, for the direction of locomotion to be changed. The five other water-striders frequently came to rest against stones and pieces of dry mud. Such contact pauses were evidences of the thigmotactic propensities of the gerrids. They also wandered from side to side of the stream bed, trying one direction for a certain length of time, and then, through the influence of some stimulus, trying another. However, they made only a very few turns, directly away from the downstream pool during their entire journey. One water-strider crawled under a piece of dried mud and remained there for three minutes.

There were twelve other water-striders that have not yet been accounted for. Four of these wandered upstream and from one bank of the brook to the other, first in one direction and then in another. Sometimes they stopped with their bodies in contact with some obstacle in their path. Frequently the direction was changed when they renewed the journey. The gerrids did not turn downstream for any considerable distance during any of their movements. After having observed them at intervals for two hours, I decided that they were unlikely to reach the water unless they eventually should wander to a pool somewhere upstream. The gerrids had moved away from the site of the former pool to such a distance that the water-strider farthest upstream was twenty yards distant from the starting point. One individual crawled under a piece of driftwood and had been in that situation for twenty-five minutes, when the observations were discontinued. Another water-strider crawled among some dead leaves and was there for twenty minutes previous to the time when I left that place for observations elsewhere.

Of the eight gerrids that have not yet been mentioned, three of them stumbled toward the left bank and five of them wandered toward the right bank of the brook. There were various obstacles in their paths, such as small rocks, pieces of dry mud, dead leaves and driftwood. The water-striders frequently came to rest in close contact with these objects—response to contact being a prominent feature in the behavior of these gerrids—and at length two of those, that had moved toward the left bank of the stream, jumped into a large crack formed in the baked mud of the bed of the brook. I observed these individuals from time to time—for at least three hours—until I left for Urbana, at about 8:00 P.M., and they were still in the same situation. I should state here that I searched for these two gerrids the next day and was unable to find them; nor was I able to discover the other four water-striders—to which I already have referred—that had moved upstream. The responses of one of the three gerrids, that in the first instance had moved toward the left bank of the brook, have not yet been described completely. After reaching the bank, it began to jump downstream. This continued for a distance of two yards, when it turned, facing the right bank of the stream, and jumped in that direction for one yard until it reached the middle of the brook channel. The gerrid again turned to the left, this position directing its head downstream, in which general direction it continued to travel, until after a number of stops, it eventually reached the large pool. In passing over its entire route, this water-strider consumed fifteen minutes.

It has been stated that five gerrids wandered toward the right bank of the brook, on first leaving the site of the former pool. Three of these turned toward the middle of the stream channel and jumped upstream for two yards, turning to the left, they moved toward the bank of the brook. On reaching it, first one and then the others jumped downstream. After a number of pauses and deviations to the right and left, two of them again turned with their heads directed upstream and continued to jump and walk in that general direction. After several erratic movements and two stops, the third gerrid turned upstream. The insect jumped in this direction for three yards and then stopped with its body in contact with a small rock. It remained in that position for five minutes. In the meantime, the two other water-striders had worked still farther upstream. On going back to observe the gerrid that had been resting against the rock, it was discovered that this insect had moved away and was walking upstream. These three water-striders were observed for 1 hour and 50 minutes and as there appeared to be less and less possibility of their reaching the large pool downstream, the observations were discontinued. When the insects were noticed last, they had traveled eighteen yards upstream away from the site of the former pool, from which they originally came. One of them had crawled under a piece of driftwood and had been there for thirty minutes when I discontinued my observations. These gerrids were sought carefully the following day, but I was unable to find them.

The wanderings of two water-striders, out of the group of five, have not yet been traced. Attention already has been directed to the fact that, when they first left the site of the former pool, they wandered toward the right bank of the brook. After reaching this point, they turned downstream. I lost sight of one of them, while observing some of the other gerrids, and I was not able to find it again. The other water-strider proceeded downstream, but frequently deviated from a straight path, and often paused with its body in contact with various obstacles. After wandering downstream for three yards, it made a complete turn and its head thus pointed upstream. This occurred as the insect was making a jump, it appearing to lose control of the orientation of its body. The water-strider moved upstream for two feet and then turned to the left, walking in that direction for four feet. The gerrid made a wide turn to the left, so that its head was directed downstream. After much erratic wandering, it eventually blundered upon the large pool of water, having consumed forty minutes in completing the journey. It was a task of considerable difficulty to keep all the gerrids under observation, because, being almost the color of the background, they were very inconspicuous.

I have records of a number of other instances, treating of my observations on the responses of water-striders after the drying up of several other stream pools, at different times and during different seasons. Some of these pools were at distances of less than ten yards, while others were eleven, twelve, and fourteen yards distant from the original pool on which the water-striders lived. It is true that, on the particular occasion to which attention has been directed and which has been described in some detail, half of the gerrids entrapped on the surface of the pool escaped—when it became dry—to another and larger body of water by making their way overland. But in all the other instances that were recorded in my field notes of similar phenomena, a very much smaller percentage of the entrapped gerrids was successful in reaching other bodies of water, after their own pool became dry. I will give a few examples: In one instance, only two of the trapped water-striders out of eight reached the surface of another pool, situated about eleven yards upstream. This was not accomplished until the gerrids had consumed much time in random movements, stops and deviations from the straight path. At another time, fifteen gerrids were trapped in a pool along the bed of a brook that had become almost dry, owing to a prolonged drought. Five water-striders out of the fifteen, or one third of the total number, only, were able to find another pool of water seven yards upstream from the point where they had been isolated. These gerrids made many trials, errors, delays, and turnings before they reached the surface-film. On still another occasion forty water-striders were entrapped on the surface of a stream pool. After the water had disappeared entirely, the hemipterons left their haunts, and stumbled along the dry bed of the stream. After much wandering about, first in one direction and then in another, six of the gerrids found a pool fourteen yards downstream from their former abode. The method of reaching the water seemed to be due to a crude form of trial and error.

I am inclined to believe that in periods of severe drought, large numbers of apterous individuals die. If the drought is a short one, and there is a certain minimum of dampness under logs, stones, and clumps of dead leaves, some of the water-striders may survive in such situations. In regard to physical conditions of a somewhat comparable character, Kirkaldy (1899, pp. 109, 110) makes the following statement with reference to *Gerris lacustris* Linné:

> In small wayside pools or streamlets which dry up periodically, it is obvious that the apterous inhabitants will die out unless their habitat is sufficiently near to a larger stream or pond; a severe drought occurring over a fairly large area, prolonged sufficiently to dry up all the water within that area, would cause all the species represented in that year by apterous individuals only to become extinct.

After having observed the erratic, aimless character of the responses of these insects, *Gerris remigis,* their ability to reach some other distant body of water appeared doubtful, and very largely dependent upon chance. If a larger body of water should be very near to the haunts of the gerrids, then there would be, through their random journeys, a greater possibility of reaching such a situation. In any case, their responses appear to be responses of repeated trial and failure, until through many repetitions, some gerrids eventually reach the water.

III. EXPERIMENTS IN CONNECTION WITH BROOK HABITAT AT WHITE HEATH

1. Methods.—I now wish to record certain other observations, on the responses of *Gerris remigis,* of a somewhat different character from those that already have been discussed. Many times when out in the field collecting *Gerris remigis,* some water-striders escaped while I was picking them out of the net as it lay on the ground near the margin of the stream. I noticed that these individuals generally found their way back on to the surface of the water. Several times it occurred to me to undertake a series of experiments with these water-striders for the purpose of discovering their ability to return to their own habitat after having been removed from it. The plan was to place them on the ground at various distances away from the stream and observe whether or not they returned to the water, and if so to record the readiness with which this was done. Up to the present, the experimental work has not yet been carried out as extensively as was desired, but the results that have been obtained may be of interest. The experiments were undertaken at the brook near White Heath, that has been mentioned previously. The site selected was at a place where the bank was flat, with its surface raised only a few inches above that of the water.

2. Responses When Facing Brook.—Twenty gerrids with their heads turned directly toward the stream, were placed on the ground one yard away from the water. All those that got back to the water succeeded in reaching the surface-film in less than one minute. Similar experiments were repeated for four successive times, using different individuals. There was no experiment in which more than two gerrids failed to reach the water. Other experiments were carried out in which the water-striders were placed two, three, and four yards away from the stream. The majority of the gerrids found their way back to the water. All those that were taken two and three yards away from the stream were back on the surface-film within 2 minutes and 30 seconds. Gerrids that were placed on the ground four yards away from the brook evinced a few more random movements than was the case of those nearer to the water. A slightly smaller percentage of the gerrids found the way back to the stream from this distance. Those water-striders that reached the surface of the brook did so within four minutes from the time each experiment began.

3. Responses When Parallel with Brook.—A series of experiments were performed identical to those already described, except that the water-striders were placed on a line with the long axis of their bodies parallel with the bank of the stream. It was observed that the majority of the gerrids were successful in reaching the water. In the case of some individuals, a longer time elapsed than was true in the first series of experiments. But most of the water-striders either turned at once toward the brook, or else they did so a few seconds after the first locomotor movements began. In some instances the gerrids jumped, for one yard or more, in the direction in which their heads were directed, before turning toward the brook. Some gerrids were placed on the ground four yards distant from the water. Certain individuals of these evinced some hesitancy in jumping directly toward the brook and there were a number of random movements.

4. Responses When Facing Away from Brook.—Other experiments, of a character similar to those that already have been described, were carried out, in which the heads of the water-striders were directed away from the stream. As before, a majority of the gerrids were successful in reaching the water. The same distances were used as in the former experiments, but in all cases there was less promptness in moving toward the brook. It also was evident that there were more random movements than was true in the former experiments. Of the water-striders placed four yards away from the stream, a greater percentage, than in any of the other experiments, failed to reach the water.

These hemipterons employed two methods of locomotion on land, walking and jumping. The more rapid progress was made by jumping. The individual jumps averaged about one inch in length, although frequently they were greater than this. Sometimes when jumping, the gerrids made a complete turn, as if they were not able, fully, to control the orientation of the body, and this frequently resulted in changing their direction of progress. In this connection, I wish to direct attention to the fact that Essenberg (1915, p. 399) has observed a somewhat similar response on the part of *Gerris orba* Stål and makes the following statement:

> It runs with a jerking motion, making from four to six jumps in succession and then making a short stop. Very often it turns a somersault and continues running without interrupting its course until it reaches a place of safety. There it lies quietly for from fifteen to twenty-five minutes, then suddenly begins its race again.

Often during one of these jumping movements, the water-striders struck against some obstacle and when this occurred, their direction of progression was changed. There was some tendency for the gerrids to continue to move in the direction which they already had taken, without regard to the position of the stream. In the three series of experiments it is of interest to notice that the water-striders reached the brook with a fair degree of directness. It was only in the series of experiments, in which the heads of the gerrids were turned away from the water, that there was much evidence of lack of promptness in turning toward the brook and of random movements.

5. *Experiments with Barrier.*—In the experiments that have been described, I felt that the sense of sight was the important factor in directing the water-striders to the brook. However, there was always the possibility that moisture, as a stimulus, might influence the responses of the gerrids. Therefore, I planned a number of experiments for the purpose of obtaining more definite information on this subject. My idea was to arrange a sort of barrier, along a limited section of the bank of the brook, which was to be of such construction as to permit diffusing moisture to pass through it readily, but on the other hand, the barrier was to be so opaque that the reflection from the water of either sunlight or diffuse daylight could not be seen through it. The barrier first employed was made of roughly interwoven leafy branches of trees. This was held in position by wooden stakes. It was four feet high and extended along the bank of the stream for a distance of approximately fifteen yards. There were two reasons for employing a barrier of this character: first, the readiness with which the materials could be obtained; and second, the fact that its appearance was in harmony with the general environment. However, it was found to be practically impossible to make it sufficiently tight so as to prevent reflections from the surface of the water from passing through it.

A number of series of experiments were tried with water-striders placed on the ground one yard and also three yards away from the brook. While the experiments were not sufficiently satisfactory, as a basis for definite conclusions, it may be stated that the gerrids displayed somewhat less promptness in reaching the water than was the case when such a barrier was absent. However, in general it was evident that the water-striders jumped toward the brook with considerable expedition and definiteness. If the barrier had proved to be lighttight, I should have been inclined to explain such a measure of promptness in moving to the water as due, perhaps, to the effect of moisture from the stream.

Of course if the means of finding the brook was mainly through vision, it was to be expected that the gerrids would be a little less prompt in reaching the water, because less reflection from the surface of the brook could be seen than was true with the barrier removed. Unfortunately the movements of the leaves by the wind permitted many bright reflections to pass through the barrier. Lying flat on the ground, with my eyes as close to it as practicable, in order to take a position as nearly the same as possible to that of the water-striders, I found that I was still able to see the bright sunlight of the hot summer day, reflected from the surface of the water. I planned to use another form of barrier and test this matter fully, when, because of the character of the season, I was compelled to take up certain other observations, and I have not yet had the opportunity to supplement this work with additional experiments.

(*To be continued*)